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Certified by



Jon W Dudas

Acting Under Secretary of Commerce  
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: John Mak

For: Flexible NGL Process and Methods

Mail Stop Provisional Patent Application  
Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

COVER SHEET FOR FILING PROVISIONAL APPLICATION  
(37 C.F.R. § 1.51(c)(1))

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 C.F.R. § 1.51(c)(1)(i). The following comprises the information required by 37 C.F.R. § 1.51(c)(1):

1. The following comprises the information required by 37 C.F.R. § 1.51(c)(1):
2. The name of the inventor is (37 C.F.R. § 1.51(c)(1)(ii)):

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3. The title of the invention is (37 C.F.R. § 1.51(c)(1)(iv)):

Flexible NGL Process and Methods

4. The name, registration, customer and telephone numbers of the practitioner are (37 C.F.R. § 1.51(c)(1)(v)):

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5. The docket number used to identify this application is (37 C.F.R. § 1.51(c)(1)(vi)):

Docket No. 100325.0235PRO

6. The correspondence address for this application is (37 C.F.R. § 1.51(c)(1)(vii)):

Rutan & Tucker, LLP  
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7. Statement as to whether invention was made by an agency of the U.S. Government or under contract with an agency of the U.S. Government. (37 C.F.R. § 1.51(c)(1)(viii)).

This invention was NOT made by an agency of the United States Government, or under contract with an agency of the United States Government.

8. Identification of documents accompanying this cover sheet:

A. Documents required by 37 C.F.R. § 1.51(c)(2)-(3):

Specification:	No. of pages	13
Drawings:	No. of sheets	3

9. Fee

The filing fee for this provisional application, as set in 37 C.F.R. § 1.16(k), is \$160.00 for other than a small entity.

10. Fee payment

Fee payment in the amount of \$160.00 is being made at this time.

11. Method of fee payment

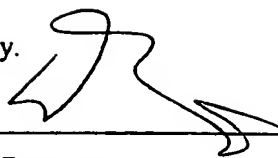
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## **FLEXIBLE NGL PROCESS AND METHODS**

### **Field of The Invention**

Gas processing, and especially gas processing for flexible ethane recovery/rejection.

### **Background of The Invention**

Expansion processes have been widely used for hydrocarbon liquids recovery in the gas processing industry, and are generally preferred for high ethane and propane recovery. External refrigeration is normally required when the feed gas contains significant quantity of the propane and heavier components. For example, in a typical turbo-expander plant, the feed gas is cooled  
10 and partially condensed by heat exchange with process streams and/or external propane refrigeration. The condensed liquid containing the less volatile components is then separated and fed to a fractionation column, operated at medium or low pressure. The remaining vapor portion is letdown in pressure in a turbo-expander to a lower pressure, resulting in further cooling and liquid formation. With the expander discharge pressure typically at the demethanizer pressure,  
15 the two-phase stream is fed to the top of the demethanizer with the cold liquids acting as the top reflux to absorb the heavier hydrocarbons. The remaining vapor combines with the column overhead as a residue gas which is then heated and recompressed to pipeline pressure.

However, in many expander plant configurations, the residue vapor from the fractionation column still contains a significant amount of ethane or propane plus hydrocarbons that could be  
20 recovered if chilled to a lower temperature, or subjected to a rectification stage. The lower temperature option could be achieved with a higher expansion ratio across the turbo-expander. Consequently, lower column pressure and higher residue gas compression horsepower are required, making high recovery uneconomical. Therefore, various NGL recovery configurations focus on an additional rectification column, and use of a colder and leaner reflux stream to the  
25 fractionation column overhead vapor.

Most NGL recovery configurations and patents generally focus on a single mode of operation, either ethane recovery or propane recovery. Thus, when such plants are required to operate on a different recovery mode, the efficiency and recovery levels suffer significantly, and

in most cases, substantial reconfiguration and operation conditions are necessary to achieve acceptable results. For example, most of the known plant configurations recover more than 98% of propane, propylene and heavier hydrocarbons during the ethane recovery, but often fail to maintain the same high propane recovery during ethane rejection. In ethane rejection operation, the propane recovery level from such processes normally drops to about 90%, thereby incurring significant loss in product revenue. Therefore, in today's volatile ethane market, the ability of ethane rejection without significant losses in propane recovery is highly desirable to maintain profitability.

Present NGL recovery systems can be classified into single-column configurations or two-column configurations, and some operating differences are summarized below. A typical single-column configuration for ethane recovery (which is also suitable for ethane rejection) is described in U.S. Pat. No. 4,854,955. Such a configuration may be employed for moderate levels of ethane recovery due to the relatively low operating temperature and pressure of the fractionation column. In such plants, the column overhead vapor is also cooled and condensed by an overhead exchanger using refrigeration generated from the feed gas chiller. This additional cooling step condenses the propane and heavier components from the column overhead gas, which is later recovered in a separator, and returned to the column as reflux. For ethane rejection, this column operates as a deethanizer, and the pressure is typically lowered to about 350 psig to generate sufficient refrigeration from turbo-expansion, and for ethane / propane separation. However, the lower column pressure generally results in an increased residue gas compression horsepower demand. Other NGL recovery configurations that employ a single column concept for both ethane recovery and ethane rejection are described in U.S. Pat. No. 6,453,698. Here, an intermediate stream is withdrawn from the column to produce a lean vapor that is further cooled and condensed to generate a lean reflux to the column. While heat integration scheme, reflux configuration and process complexity vary among many of these designs, they all tend to suffer from high energy consumption, mainly due to the lower column pressure that is needed for cooling and fractionation.

A two-column design typically uses a reflux absorber and a second column that can be operated as a demethanizer or deethanizer. The two-column design offers more flexibility

allowing the absorber and the second column to operate at different pressures if necessary. However, conventional two-column designs are generally suitable for either ethane recovery or propane recovery, but not both. Operating differently from design conditions will often incur significant propane losses (*e.g.*, may not achieve the desirable 98% plus recovery). U.S. Pat. Nos. 5,953,935 and 5,771,712 propose recycling of the overhead vapor or liquid from the second distillation column to the absorber as a lean reflux. While plants according to U.S. Pat. No. 5,953,935 may be used for high ethane and propane recoveries, the configuration is under most operating conditions incapable of rejecting ethane, and if it does, the propane losses from this process are substantial. Similarly, U.S. Pat. No. 5,771,712 is configured for propane recovery only, and when it is used for ethane recovery, the level of ethane recovery is typically limited to the 20% range. In addition, the propane recovery processes when used for ethane recovery will suffer significant propane losses.

In another approach, as described in U.S. Pat. No. 6,363,744, the residue gas stream from residue gas compressor discharge is recycled as a lean reflux in the demethanizer. Such recycling is commonly practiced to generate refrigeration for a reflux in an ethane recovery operation. However, the use of residue gas consumes a large amount of horsepower, and the cost of residue gas compression is prohibitively high and usually not economical. Moreover, for ethane recovery operations, all, or almost all of the above approaches require cryogenic operating temperatures for both the absorber and the distillation columns, consequently requiring the use of stainless steel material of construction. The cryogenic operation of the second distillation columns unnecessarily increases the cost of these installations.

Thus, numerous attempts have been made to improve the efficiency and economy of processes for separating and recovering ethane and heavier natural gas liquids from natural gas. However, all or almost all of them fail to achieve economic operation when ethane rejection is required. Therefore, there is still a need to provide improved methods and configurations for flexible natural gas liquids recovery.

### **Detailed Description**

The inventors have discovered that high and flexible NGL recovery (*e.g.*, at least 99% C3, and at least 90% C2) may be achieved, when an NGL plant includes a first distillation column (absorber) that receives at least two reflux streams. In a preferred aspect, a plant is configured as  
5 a two column plant in which a first column operates as a reflux absorber, and in which a second column operates as either demethanizer or deethanizer. Such configurations will advantageously allow change in component recovery by changing process temperature, split ratios and the feed locations to at least one of reflux streams in the absorber.

In one particularly preferred configuration, the absorber operates at a higher pressure than  
10 the second column with the bottom liquid from the absorber being JT'd (*i.e.*, let down in pressure via Joule-Thompson valve) and fed to the second column. It should be especially appreciated that the JT effect of the absorber bottom supplies a portion of refrigeration for feed gas chilling. The overhead vapor from the second column is compressed in a recycle compressor and returned to the first distillation column.

15 In another particularly preferred configuration, the absorber operates at about the same pressure as the second column with the bottom liquid from the absorber being pumped to the second column. The refrigerant content of the absorber bottom is used for chilling the feed gas prior to feeding the second column. In yet another particularly preferred configuration, the recycle compressor is driven by the power generated by the turbo-expander, eliminating the need  
20 for additional residue gas compression.

It should further be appreciated that the overhead vapor from the second distillation column is split into two portions, with the first portion chilled in a reflux exchanger with the overhead vapor from the absorber, forming a cold reflux to the top section of the absorber. The second portion of the overhead vapor forms a stripping gas that is fed to the bottom of the  
25 absorber. Therefore, the split ratio of the first portion to the second vapor portion from the second distillation column determines operation of the plant as ethane recovery (varying from 10% to 90%) or ethane rejection.



Moreover, the first distillation column is preferably also fed by a second reflux stream generated by chilling a first portion of cold vapor from the high pressure separator. This second reflux is fed to a located just below the top reflux. The second portion of cold vapor from the high pressure separator is letdown in pressure via a turbo-expander into the mid section of the absorber. Therefore, the split ratio of the first portion to the second vapor portion from the high pressure separator determines operation of the plant as ethane recovery (varying from 10% to 90%) or ethane rejection.

It is still further generally contemplated that (a) the lean vapor streams from the second column and (b) from the high pressure separator are completely or partially condensed by heat exchange with the overhead vapor from the absorber, and fed to the top section of the absorber as lean reflux streams. These two reflux streams significantly improve the separation efficiency as compared to the single reflux practiced in heretofore known configurations. During ethane recovery, the majority of the overhead vapor from the second column bypasses the reflux exchanger and is routed directly to the bottom of the absorber. This stream may advantageously serve as a stripping vapor for the absorber, thereby further enhancing the separation efficiency of the absorber. Consequently, contemplated plants will achieve even higher ethane or propane recovery from the two column process.

With respect to the liquid from the high pressure separator, it is generally preferred that the liquid is split into two portions and separately fed to the absorber. Once more, the split ratio will determine recovery in either ethane recovery at the varying levels or total ethane rejection. In especially preferred aspects, the first portion of the liquid is directly routed to a tray above the bottom of the absorber; while the second portion is heated with the inlet gas in an inlet gas exchanger and fed to the bottom of the absorber. The use of the cold liquid from the high pressure separator after being J-T'd is effective for rectification for the recycle vapor from the second column. Thus, the use of split ratio control will allow flexibility for different recovery operations.

In a particularly preferred configuration as depicted in Figure 1, a plant comprises an absorber 58 that is fluidly coupled to a distillation column 60. To achieve a very low energy in terms of residue gas compression, the absorber 58 operates at a higher pressure than the

distillation column 60. A compressor 66 is used on the distillation column overhead vapor, recycling the desirable components to the absorber for recovery. Typically, the absorber operates between 500 psig 650 psig while the second column serving as a demethanizer (during ethane recovery) or a deethanizer (during ethane rejection) operates between 400 psig to 500 psig. When  
5 the absorber operates at the lower pressures, the need of the recycle compressor can be eliminated.

The feed gas composition in mole percent in the following example is as follows: 1% CO<sub>2</sub>, 86% C<sub>1</sub>, 5% C<sub>2</sub>, 4% C<sub>3</sub>, 3% C<sub>4</sub> and 2% C<sub>5</sub>+. The feed gas stream 1, at 110°F and 1000 psig, is cooled in a heat exchanger 51 with refrigeration contents in the residue gas stream 19,  
10 separator liquid stream 8, absorber bottom liquid stream 18, and supplemental propane refrigerant stream 41 if necessary. Feed gas is cooled to -15°F to -55°F forming stream 2 which is separated in the separator 52 into a vapor stream 3, and a liquid stream 4 that is further split into stream 5 and stream 6. The split ratio is adjusted as necessary in achieving the optimum fractionation efficiency for the different levels of ethane recovery.

15 For example, when a high ethane recovery is required, the split ratio (that is, stream 5 to stream 4) is lowered, resulting in an increase in flow in stream 6 that is further letdown in pressure to about 600 psia via JT valve 54 into the rectification section of absorber 58. During ethane recovery, stream 6, containing mainly the C<sub>3</sub> and heavier components, acts as an sponge liquid for absorbing and condensing the ethane content in stream 32 rising at the bottom of the  
20 absorber. During ethane rejection, the split ratio (that is, stream 5 to stream 4) is increased, resulting in an increase in flow in stream 5. Stream 5 is letdown in pressure to about 600 psia via JT valve 53 forming stream 8. The refrigerant content of stream 8 is used to cool the feed gas in exchanger 51 while itself being heated to about -10°F to -40°F forming stream 9. Stream 9 is routed to the bottom of the absorber and provides a portion of the stripping vapor during the  
25 ethane rejection or propane recovery only operation.

The cryogenic chilling of the feed gas is achieved with vapor stream 3 from high-pressure separator 52 using both JT and turbo-expander operations. Vapor stream 3 is split into two portions, stream 11 and stream 10. The first portion, stream 11 is expanded in a turbo-expander 55 forming an expanded stream 14, typically at -75°F to -115°F, which is introduced

into the mid section of absorber 58. The second portion stream 10 is cooled in heat exchanger 56 to typically -80°F to -130°F, reduced in pressure via JT valve 57 forming a cold reflux stream 13, typically at -115°F to -140°F, feeding the absorber 58 as a second reflux stream. The split ratio is also adjusted as necessary to achieve the optimum fractionation efficiency for the different levels of ethane recovery.

For example, when high ethane recovery is required, the split ratio (that is, stream 10 to stream 3) is increased, to about 0.2 to 0.4, resulting in an increase in flow in stream 10 to exchanger 56. Stream 10 is cooled and partially or entirely condensed in exchanger 56 using the refrigeration content from the absorber overhead vapor stream 16, thereby forming stream 12. This cold stream is further JT'd, and used as a cold and lean reflux for rectification and recovery of the ethane and heavier components in the absorber. During ethane rejection, the split ratio (that is, stream 10 to stream 3) is lowered to about 0.0 to 0.2, resulting in a lower flow in stream 10, avoiding re-condensation of the ethane component, reducing unnecessary internal reflux during the ethane rejection operation. The absorber rectification section operates at a higher temperature as needed for the ethane rejection operation. For example, during ethane rejection, the absorber typically operates at about -95°F as compared to -135°F during ethane recovery operation.

To further enhance the liquid recovery efficiency, absorber 58 also receives a first reflux stream 15 that is formed from cooling a portion of the compressed vapor stream 30 from the distillation column 60. Optionally for ethane rejection, a portion of the distillate from the second distillation column, stream 42, can be used to provide additionally reflux after being J-T'd in JT valve 70 and being chilled in exchanger 56. The use of the distillate liquid from the column is particularly advantageous when processing feed gas that is rich in ethane content, preferably over 15% mole percent of ethane.

The compressed stream 30 is split into stream 31 and stream 32 with the split ratio determined by the levels of ethane recovery. During ethane rejection, the split ratio (that is, stream 31 to stream 30) is increased to about 0.8 to 1.0. Consequently, majority of the recycle stream is routed as stream 31 to be chilled and condensed in exchanger 56, forming reflux stream 15, typically between -80°F to -100°F. Stream 15 rich in the ethane content is effective as a lean

reflux for propane recovery. During ethane recovery, the split ratio is lowered 0.0 to 0.2, consequently the flow of reflux stream 31 is reduced and the flow of stream 32 is increased. The temperature of stream 32 is in a superheated state after compression, typically between 20 °F to -20°F.

5           The absorber operating between 400 psig to 650 psig produces an overhead stream 16 and a bottom stream 17. The temperatures of these two streams also vary depending on the levels of ethane recovery. For example, during high ethane recovery, the overhead temperature must be maintained at -110 °F to -145°F, as needed for recovery of the ethane and heavier components. During ethane rejection, the overhead temperature is increased to about -80°F to -100°F, as  
10 needed in rejecting most the ethane components overhead. The refrigerant content in the absorber overhead stream 15 is recovered in heat exchanger 56 by providing cooling to the first and second reflux streams 31 and 10 respectively. The residual refrigeration is then used in heat exchanger 51 for chilling the feed gas. The absorber bottom stream 17 is letdown in pressure, cooled by JT valve 59, forming stream 18, which supplies additional refrigeration in chilling the  
15 feed gas. Stream 18, typically 20°F to -40°F is heated in exchanger 51 to about 60° to 100°F forming stream 23 prior to entering the upper section of the second distillation column 60.

Distillation column 60 operates at about 400 to 500 psig serving as a demethanizer during ethane recovery operation. It fractionates stream 23 into an ethane and heavier bottom product 25 and a methane rich overhead stream 24. This column functions as a deethanizer during ethane  
20 rejection operation, producing a propane rich bottom product and an ethane rich overhead vapor. The overhead vapor is condensed using propane refrigeration stream 40 in reflux exchanger 61, forming stream 26 at about -10°F to -40°F. Stream 26 is separated in reflux drum 62 into a liquid stream 28 and a vapor stream 27. The liquid stream 28 is pumped by reflux pump 63 forming stream 29 and returned to the top of the distillation column as reflux. A portion of the distillation  
25 may be used as reflux in the absorber as previously described.

It should also be appreciated that the second column of the invention operates at -40°F or higher temperatures that allows the use of low-cost carbon steel. Conventional designs typically require operating the second column at cryogenic temperatures, that is, -40°F and below,

particularly during the ethane recovery operations, consequently requiring the use of costly stainless steel material.

The vapor stream 27 is compressed by compressor 66 to form stream 30 which is split into stream 31 (and let down in pressure via JT valve 67) and 32 (and let down in pressure via JT valve 68), either routing to exchanger 56 providing reflux and/or to the bottom of the absorber for ethane re-absorption. Heating requirement in the distillation column is supplied with side-reboiler 64 (optional) using either heat content from the feed gas or from the bottom product, supplemented with the bottom reboiler 65 using an external heat source. The temperature of the NGL bottom product ranges from 100 °F to 250°F depending on the mode of operation and ethane recovery level.

The residue gases stream 20 exits the feed exchanger 51 at about 370 psig to 600 psig is compressed by the expander compressor 55, to about 420 psig to 650 psig, to form compressed residue gas stream 21. If necessary, additional recompression with compressor 71 can be used to boost the residue gas pressure to the sales gas pipeline. Optionally, the compressor discharge vapor stream 38 is cooled in exchanger 72 forming stream 39 prior to the sales gas pipeline.

The following table shows the key process conditions, the split ratios and the refrigeration power consumption in achieving the various levels (0% to 90%) of ethane recovery and 97% or higher propane recovery. The higher ethane recovery operation requires lowering the separator (52) and absorber overhead temperature, hence an increase in refrigeration requirement that is supplied by the refrigeration compressor and/ or higher expansion ratio across the turboexpander by lowering the absorber pressure. In all operations, the second column operates at -40° or higher temperatures, requiring only carbon steel material of construction.

Operating Case	1	2	3	4	5
C2 Recovery	0%	40%	60%	80%	90%
C3 Recovery	98%	98%	97%	98%	99%
Key Process Conditions:					
Separator (52), °F	-35	-40	-52	-52	-54
Exchanger (56) Outlet, °F	-80	-100	-103	-116	-129

Separator Vapor Ratio (stream 10 to 3)	0.20	0.32	0.37	0.37	0.37
Separator Liquid Ratio (stream 5 to 4)	1.00	1.00	0.80	0.60	0.25
Recycle Vapor Ratio (stream 31 to 30)	0.83	0.35	0.00	0.00	0.00
Absorber Overhead, °F	-83	-104	-107	-121	-134
Absorber Overhead, psia	588	588	588	498	418
Recycle Compressor (66), HP	665	693	705	612	not req'd
Refrigeration Compressor, HP	7,817	7,026	10,656	11,751	14,390

In second particularly preferred configuration as depicted in **Figure 2**, a plant comprises an absorber 58 that is fluidly coupled to a distillation column 60, with the absorber operating at about the same pressure as the distillation column. In this configuration, the absorber operates at about 400 psig to 500 psig with the distillation column operating at about 410 psig to 510 psig. With the second column operating at a slightly higher pressure, recycle compressor 66 is not required. This case is shown as Operating Case 5 in Table 1 when high ethane recovery of 90% is desired.

The process conditions, in particular the split ratios for different levels of ethane recovery are similar to the previous design. The exception is that the recycle compressor 66 is not required, and the overhead vapor can be routed directly to the exchanger. In addition, an absorber bottom pump 59 is required to boost the absorber bottom pressure to feed the second distillation column. With respect to the remaining components and numbering, the same numerals and considerations as in Figure 1 apply.

In a third particularly preferred configuration as depicted in **Figure 3**, a plant comprises an absorber 58 that is fluidly coupled to a distillation column 60, with the absorber operating at a higher pressure than the distillation column. In this configuration, the absorber operates at above the sales gas pressure of about 510 psig to 610 psig, without the need of a separate residue gas compressor 71. The second distillation column operates at a lower pressure, typically between 300 psig to 400 psig, with the overhead vapor compressed by the recycle gas compressor 66 driven by the turbo-expander 55, returning to the absorber after being chilled in exchanger 56. Other process parameters are similar to configuration described in Figure 1. Again, with respect to the remaining components and numbering, the same numerals and considerations as in Figure 1 apply.

With respect to suitable feed gas streams, it is contemplated that various feed gas streams are appropriate, and especially suitable feed gas streams may include various hydrocarbons of different molecular weight. With respect to the molecular weight of contemplated hydrocarbons, it is generally preferred that the feed gas stream predominantly includes C<sub>1</sub>-C<sub>6</sub> hydrocarbons.

5 However, suitable feed gas streams may additionally comprise acid gases (e.g., carbon dioxide, hydrogen sulfide) and other gaseous components (e.g., hydrogen). Consequently, particularly preferred feed gas streams are natural gas and natural gas liquids.

In still further preferred aspects of the inventive subject matter, the feed gas streams are cooled to condense at least a portion of the heavier components in the feed gas stream, and in  
10 especially preferred configurations, the feed gas stream is cooled, separated into a vapor portion and a liquid portion, wherein the vapor portion is further cooled and separated into a second vapor portion and second liquid portion. While not limiting to the inventive concepts presented herein, it is particularly preferred that these cooling steps may be achieved using the refrigerant content of the absorber overhead product and/or the absorber bottom product.

15 In contemplated configurations, it is further preferred that the separated liquids from the feed gas stream are fed into the absorber at the lower section for rectification. With respect to the vapor portions, it should be recognized that the second vapor portion is split into a bypass stream and a turbo-expander stream, wherein the turbo-expander stream is fed into a turbo-expander and subsequently into the absorber, and wherein the bypass stream is further cooled, preferably using  
20 the refrigerant content of the absorber overhead product, and then let down in pressure via a device other than a turbo-expander before entering the upper section of absorber as a first second reflux stream. Especially suitable devices include Joule-Thomson valves, however, all other known devices and methods to reduce pressure are also considered suitable for use herein. For example, suitable alternative devices might include power recovery turbines and expansion  
25 nozzles devices.

In still further contemplated configurations, it is preferred that the overhead vapor from the second distillation column is split into two portions with one being fed into the absorber as a first reflux to the absorber or to the lower section for rectification in recovery of the ethane components. With respect to the vapor portions, it should be recognized that the reflux vapor

portion is fed into an overhead exchanger that is cooled and condensed by the absorber overhead vapor prior being used as reflux into the absorber, and wherein the bottom portion is routed directly to the bottom of absorber for ethane recovery.

5 The absorber overhead and bottom products are preferably employed as refrigerant in a heat exchanger, wherein the heat exchanger provides cooling for the first and second reflux streams. Furthermore, it is preferred that the absorber overhead product may act as a refrigerant in at least one, and preferably at least two additional heat exchangers, wherein the absorber overhead product cools the separated vapor portion of the feed gas and the feed gas stream before recompression to residue gas pressure. Similarly, the absorber bottom product is employed as a  
10 refrigerant to cool the feed gas stream before entering the distillation column as column feed. Suitable absorbers may vary depending on the particular configurations, however, it is generally preferred that the absorber is a tray or packed bed type absorber.

The absorber bottom product is separated in a distillation column to form the desired bottom product (*e.g.*,  $C_2/C_3+$  or  $C_3$  and  $C_4+$ ). Consequently, depending on the desired bottom  
15 product, appropriate distillation columns include a demethanizer and a deethanizer. Where the desired bottom product is  $C_3$  and  $C_4+$ , it is contemplated that the distillation column overhead product is cooled in a cooler (*e.g.*, using external refrigerant) and separated into a distillation column reflux portion and a vapor portion. Thus, it should be especially appreciated that the vapor overhead product from the distillation column is further split and may be employed as a  
20 reflux stream for the absorber, wherein the reflux stream is a lean reflux stream that is fed to the top tray of the absorber.

Similarly, where the desired bottom product is  $C_2/C_3+$ , it is contemplated that the distillation column overhead product bypasses the cooler and the vapor portion is employed as a bottom feed to the absorber. Again, it should be especially appreciated that in such configurations  
25 of ethane recovery, the vapor overhead product from the distillation column is recycled back to the absorber for re-absorption of the  $C_2$  plus components resulting in high ethane recovery.

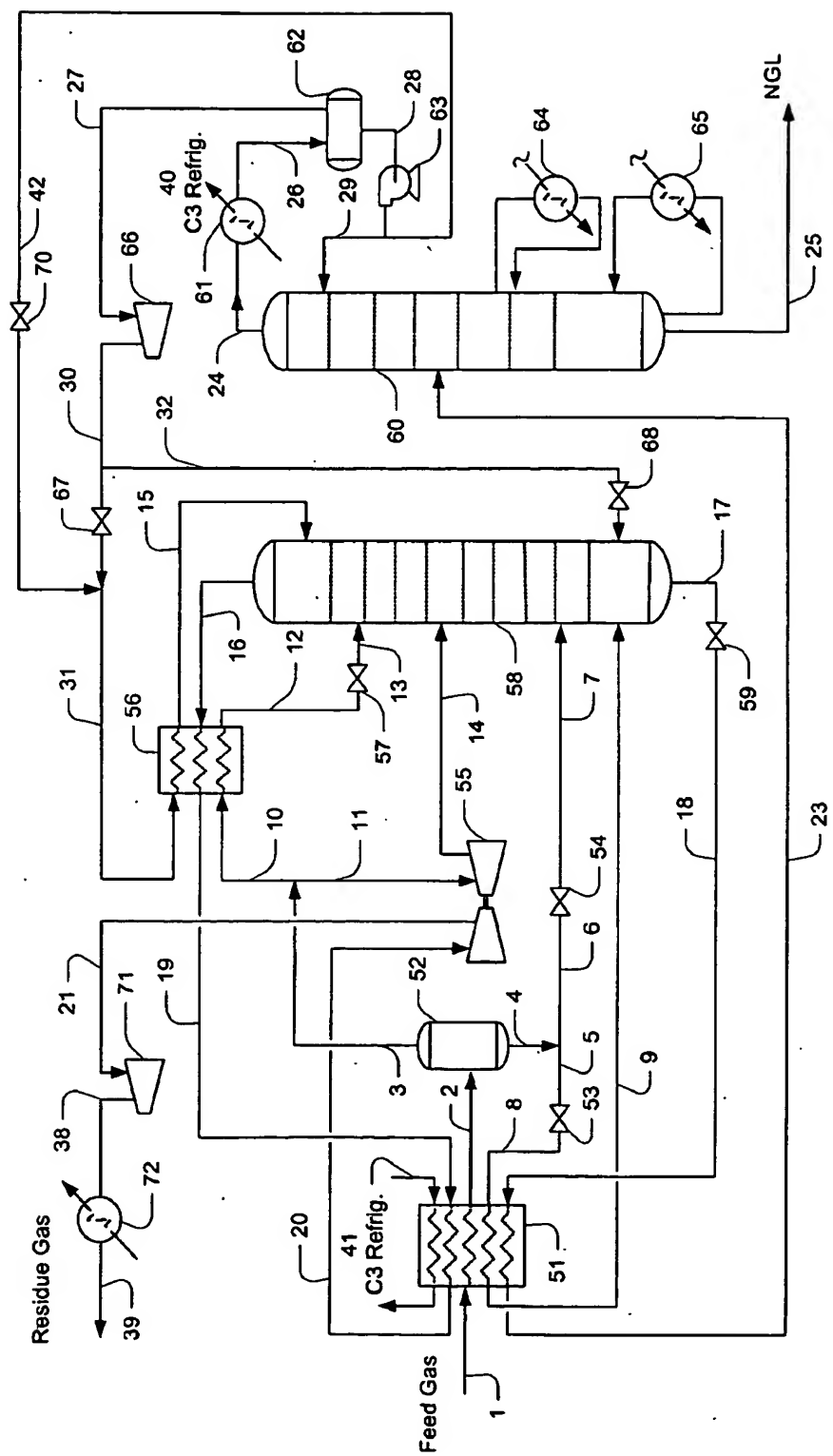
For intermediate levels of desired  $C_2/C_3+$ , bottom product, it is contemplated that the distillation column overhead product partially bypasses the cooler and the vapor portion is



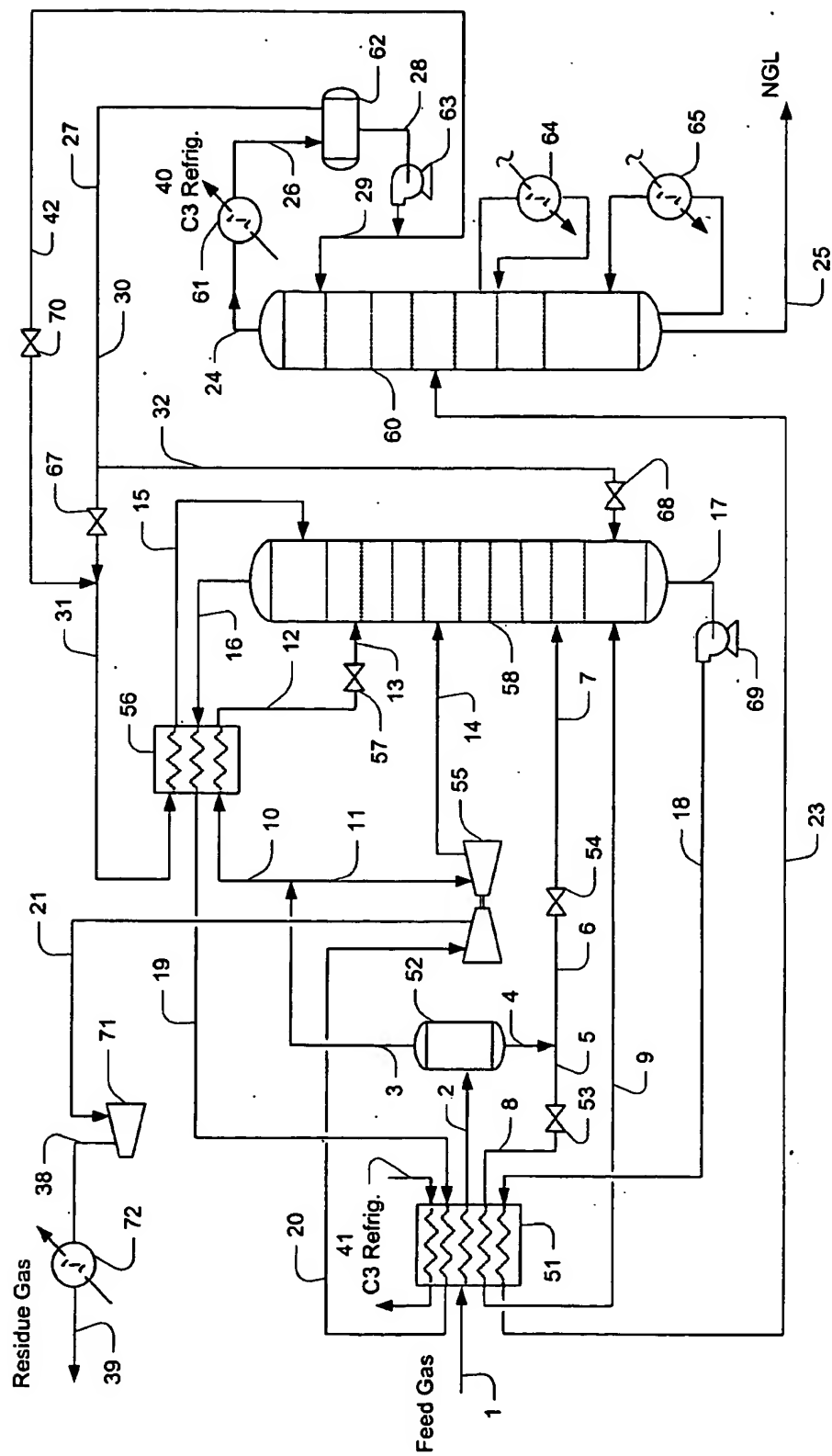
employed as a bottom feed to the absorber. Again, it should be especially appreciated that in such configurations of ethane recovery, only a portion of the vapor overhead product from the distillation column is recycled back to the absorber for re-absorption of the C<sub>2</sub> plus components resulting in high ethane recovery.

5           Thus, it should be especially recognized that in contemplated configurations, the cooling requirements for the absorber are at least partially provided by the reflux streams (via cooling by absorber bottom and overhead products), and that the C<sub>2</sub>/C<sub>3</sub> recovery significantly improves by employing a first and a second reflux stream. With respect to the C<sub>2</sub> recovery, it is contemplated that such configurations provide at least 85%, more typically at least 88%, and most typically at  
10   least 90% recovery, while it is contemplated that C<sub>3</sub> recovery will be at least 95%, more typically at least 98%, and most typically at least 99%.

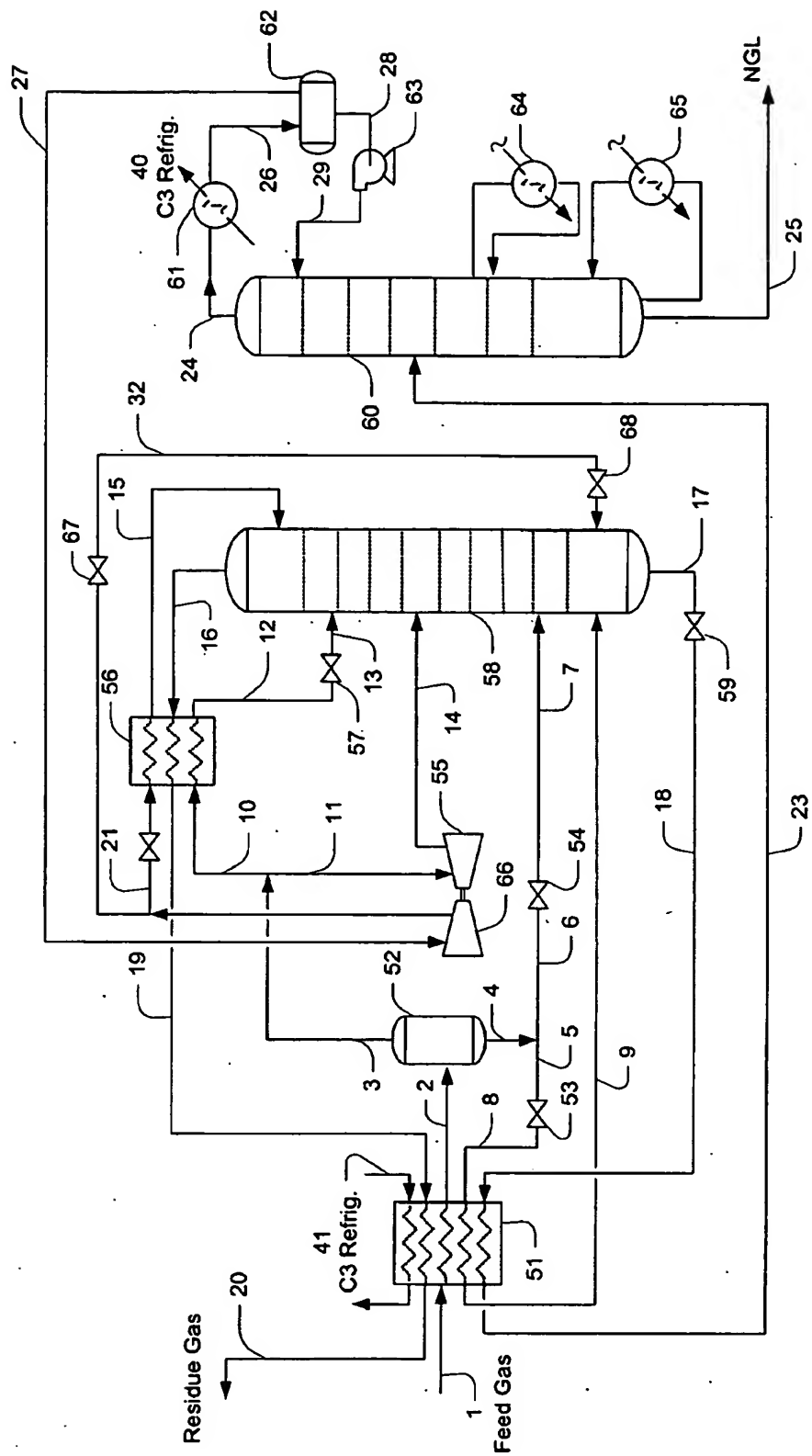
          Thus, specific embodiments and applications of flexible NGL processes and methods have been disclosed. It should be apparent, however, to those skilled in the art that many more modifications besides those already described are possible without departing from the inventive  
15   concepts herein. The inventive subject matter, therefore, is not to be restricted except in the spirit of the appended claims. Moreover, in interpreting both the specification and the claims, all terms should be interpreted in the broadest possible manner consistent with the context. In particular, the terms "comprises" and "comprising" should be interpreted as referring to elements, components, or steps in a non-exclusive manner, indicating that the referenced elements,  
20   components, or steps may be present, or utilized, or combined with other elements, components, or steps that are not expressly referenced.



**Figure 1**



**Figure 2**



**Figure 3**

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